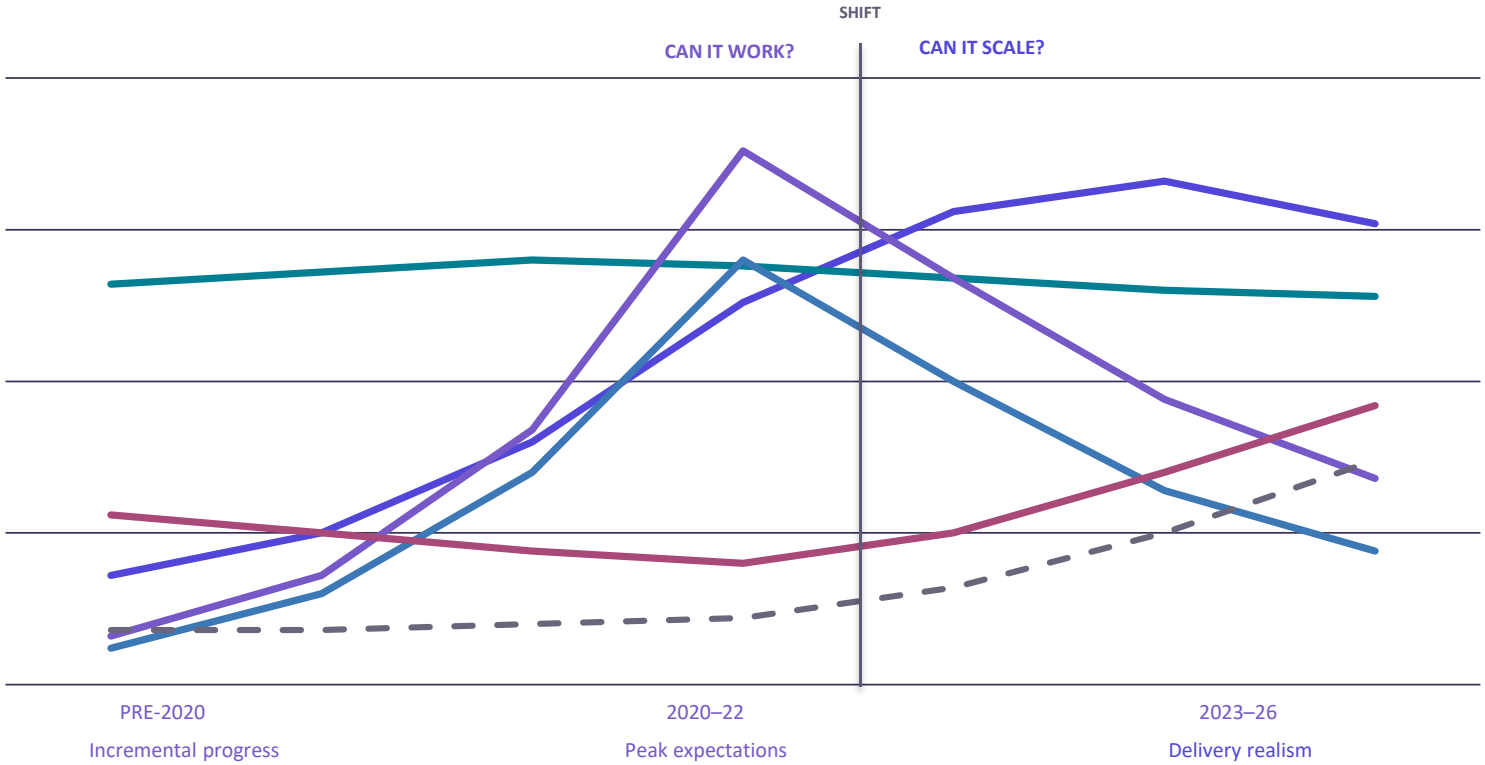
GSA2: Super Panel: Pathways to Sustainable Aviation Perspectives & Progress on NextGen Propulsion for Future Airliners

Alan Newby on behalf of the panel:

- Andrew Murphy (Pratt and Whitney
- Alan Newby (Rolls-Royce)
- Christine Andrews (GE)
- Eric Dalbies (Safran)



Net zero aviation: ambition meets reality



SAF
scaling anchor

EFFICIENCY
no-regret fundamental foundation

REMOVALS
Integral part of solution

DEMAND RESPONSE
cost-sensitive avoided growth

HYDROGEN
Strategic long term option

ELECTRIC
mission-specific niche

Illustrative synthesis based on [illegible] 2023 and 2026 roadmaps. Qualitative prominence—not forecast contribution.



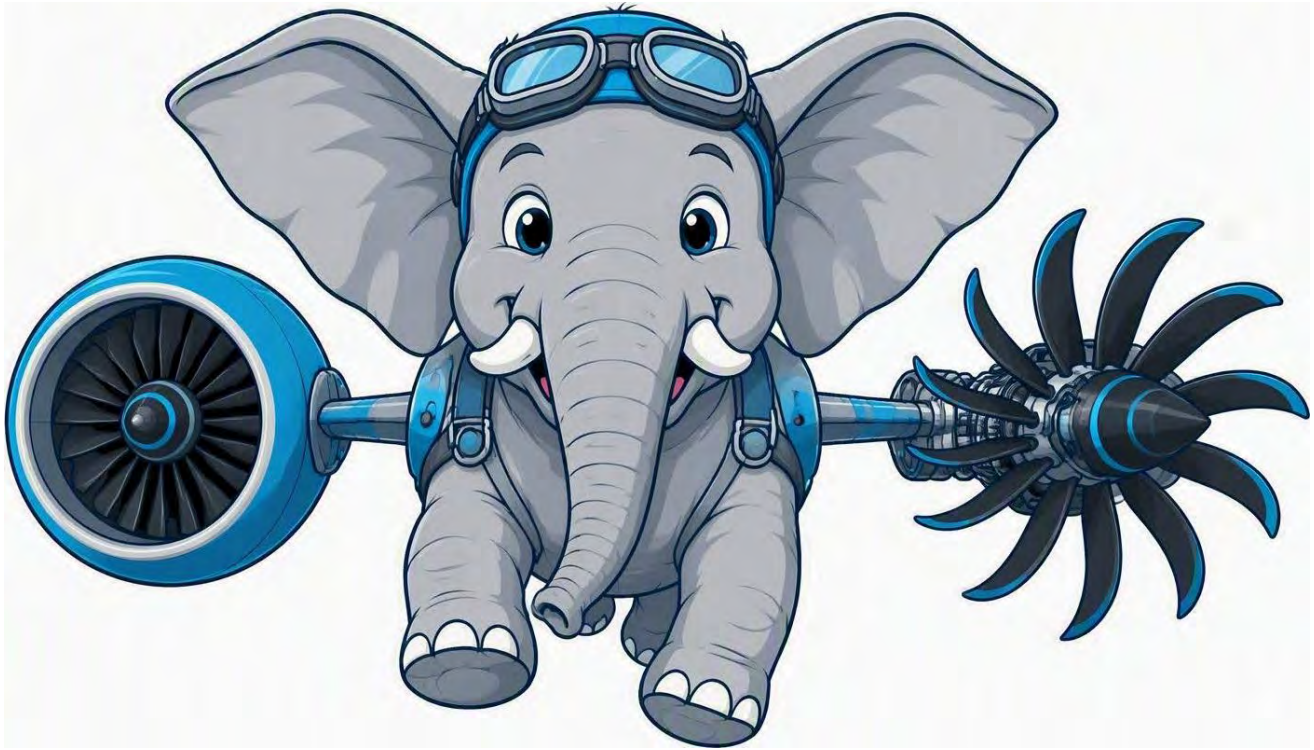
Next Generation propulsion summary- technical

Consistent Messages – Key areas of agreement

- Whilst **advanced fuels** such as hydrogen and LNG **remain very promising** future options these will be applicable N+2 concepts rather than the next generation, hence **next generation engines will be highly efficient gas turbines and SAF fueled**
- Next gen aircraft require a **step change in efficiency**, and this will be achieved through
  - Advanced propulsors
  - High technology compact core systems
  - Application of hybrid electric technology
- **Advanced materials** continue as an essential and underpinning capability
- **Noise and emissions remain critically important**
  - This includes NOx, particulates and non-CO2



One area we didn't show consensus – the elephant in the room!



ADVANCED DUCTED TURBOFAN

OPEN FAN



Next Generation propulsion summary – Broader Issues

Consistent Messages – Key areas of agreement

- Next generation engines must take a broader **system level approach** in their design to balance the traditional performance parameters with:
  - Durability
  - Produceability
  - Maturity
  - OE and MRO costs
- Lessons learned from current programs combined with significant ramp up rates for next generation propulsion systems mean **manufacturability and supply chain resilience need to be designed in**
- We have moved from a period of significant **R&D into technology development**. This presents challenges and opportunities from a **people** perspective:
  - Threat of teams not being match fit
  - Opportunity to accelerate people development through R&T programmes and keep match it on complex systems integration



Next Generation propulsion summary – Looking Forward

What are the key factors that will shape the future over the next few years?:

- How we embrace and apply AI
- Will changing world mean that the future market continues to be an extrapolation of the past ?
- We cannot assume that the global order underpinning today's highly efficient supply chains will endure; we must therefore invest in advanced manufacturing technologies and design supply chains for resilience.
- We face a demographic challenge and need a continued pipeline of new talent



Boeing Global Technology

Technology Innovation: Solving Today, Building Tomorrow

Vice President

Michael Edwards

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Boeing Engineering & Technology Innovation



Quantum and Cyber

Quantum Compute
Quantum Sensing & Navigation Solutions
Semiconductors & Microelectronics



Artificial Intelligence & Autonomy

Safety-critical AI & Autonomous Systems
Digital Inspection & Quality Assistants
Engineering Productivity
AI-Enhanced Design and Simulation

Digital Engineering

Digital Threads/ Twins
Multidisciplinary Design
Software Centric Design



Connectivity

Reusable Launch Vehicles
Satellite Communications
Electronic Warfare Applications





Energy

Advanced Wing Technologies
SAF, Cryofuels, & Dual fuels
Electrification
Integrated Power & Thermal Management



Next-Gen Materials & Structures

Novel Alloys
3D Printing
Lightweight Composites

Operational Efficiency

Trajectory-Based Operations
AI Trainer and AI co-pilot in the sim
Smarter Services



Advanced Manufacturing

Robotics & Automation
Producibility for Rate and Flow
Smart Factories



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The Aeronautics Outlook, Director's Cut

The Future Aerospace Engineer: Preparing Talent For The Challenges For AI-enabled, Digitally Integrated World

Presented by:

Prof. Dimitri Mavris

President Emeritus of ICAS

Distinguished Regents Professor

Georgia Institute of Technology

ICAS

International Council of the Aeronautical Sciences

Version: Jan 2021

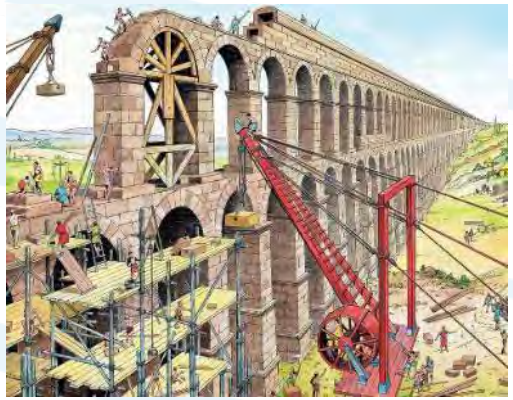
Engineering by Experience

International Council of the Aeronautical Sciences

An evolution presented primarily from a Western perspective, while parallel and distinct developments occurred across the rest of the world

Pre-19th Century
Craft & Practice

- Engineering did not exist as a distinct profession
- The professional work before industrialization was organized around craft guilds and apprenticeships, not through formal schooling
- The skills required were about **manual dexterity** and **tacit knowledge** passed from master to apprentice; “know how to build”



The Roman Aqueducts [1]



The Antikythera Mechanism [2]

Engineering by Calculation



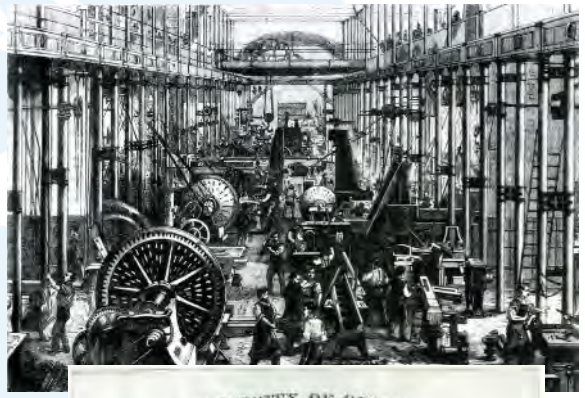
- Steam engines, railways, factories, telegraphy, etc. created systems that were increasingly too complicated to design purely through craftmanship
- Gradually transitioned from craft to applied sciences
- Engineering universities began appearing:
  - École des Ponts et Chaussées (France, 1747) — first engineering school
  - École Polytechnique (France, 1794) — the model much of the world copied, heavy on math/science theory
  - Rensselaer Polytechnic Institute (US, 1824) — first US engineering degree-granting school
  - MIT (1861), founded explicitly to blend theory with hands-on "learn by doing"
- Typical 19th century colleges taught mathematics, mechanics, drafting, surveying, thermodynamics, materials strength, etc. as industrial processes scaled
- The engineer became someone who could **both calculate and build**

The Rise of Engineering Degrees

- Schools mirrored the factory model in how they operated, emphasizing practical training and the application of science to real-world problems
- Aeronautical engineering became institutionalized as a distinct discipline in the 1920s, accelerated by the Daniel Guggenheim Endowment's support of seven major U.S. aeronautics schools and laboratories
- Engineering education began moving from apprenticeship to the classroom, as universities increasingly formalized technical knowledge that had traditionally been learned through hands-on practice

Pre-19th Century
Craft & Practice

19th Century
Professionalization





(top) depiction of industrial revolution [3], (bottom) first degree awarded from Georgia Tech [4]

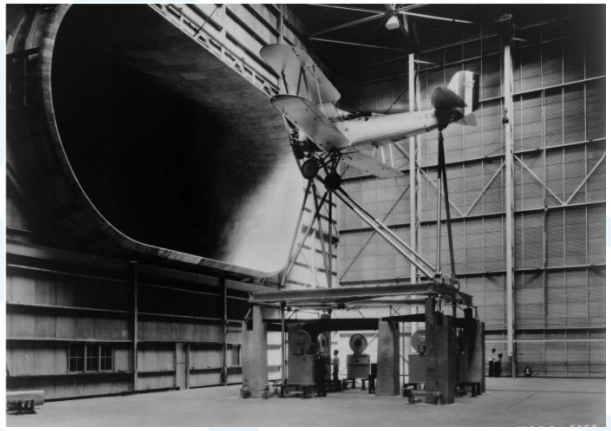
Engineering by Science

Pre-19th Century
Craft & Practice

19th Century
Professionalization

Early 20th Century
Engineering Science

- Engineering education began moving away from narrow, practice-specific training toward stronger foundations in mathematics and the physical sciences
- Engineering problems were increasingly treated analytically
  - mechanics, strength of materials, fluid mechanics, thermodynamics, vibrations, etc. were used to **model and predict physical behavior**

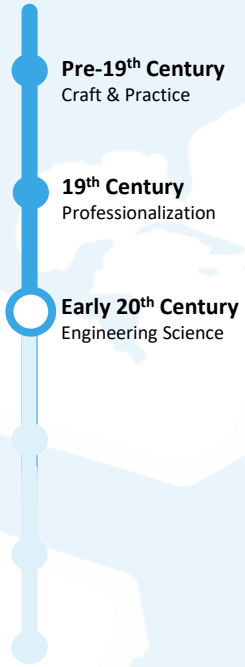


Full scale wind tunnel, 1930s, [5a]



Drafting room, 1930s, [5b]

What Changed During WWII?



- Important point in this timeline because it exposed a limitation in the pre-war engineering model
- During the war, engineers were **encountering technologies for which the established engineering knowledge does not yet exist**
  - Distinction between scientist and engineer blurred
- WWII introduced problems at the frontier of science
  - Radar, Guidance & Control, Advanced Aerodynamics, Rapid development & Mass Production, System Integration, Experimental Engineering…

What Changed During WWII?

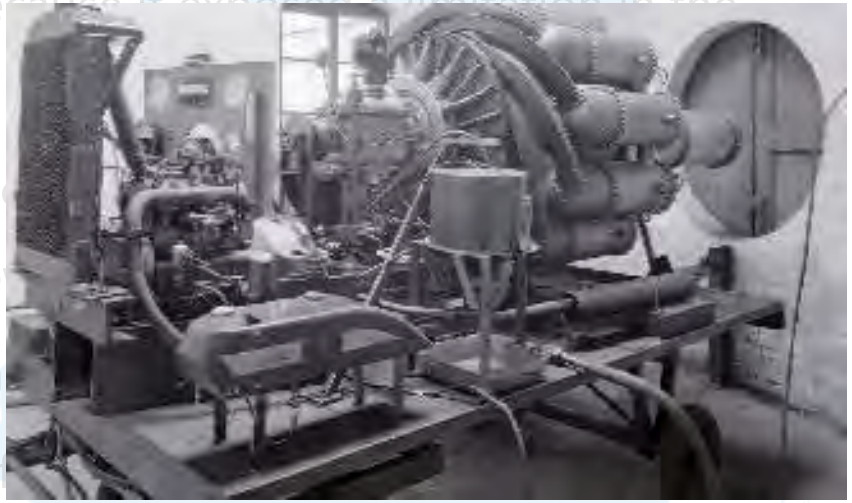
Pre-19th Century
Craft & Practice

19th Century
Professionalization

Early 20th Century
Engineering Science



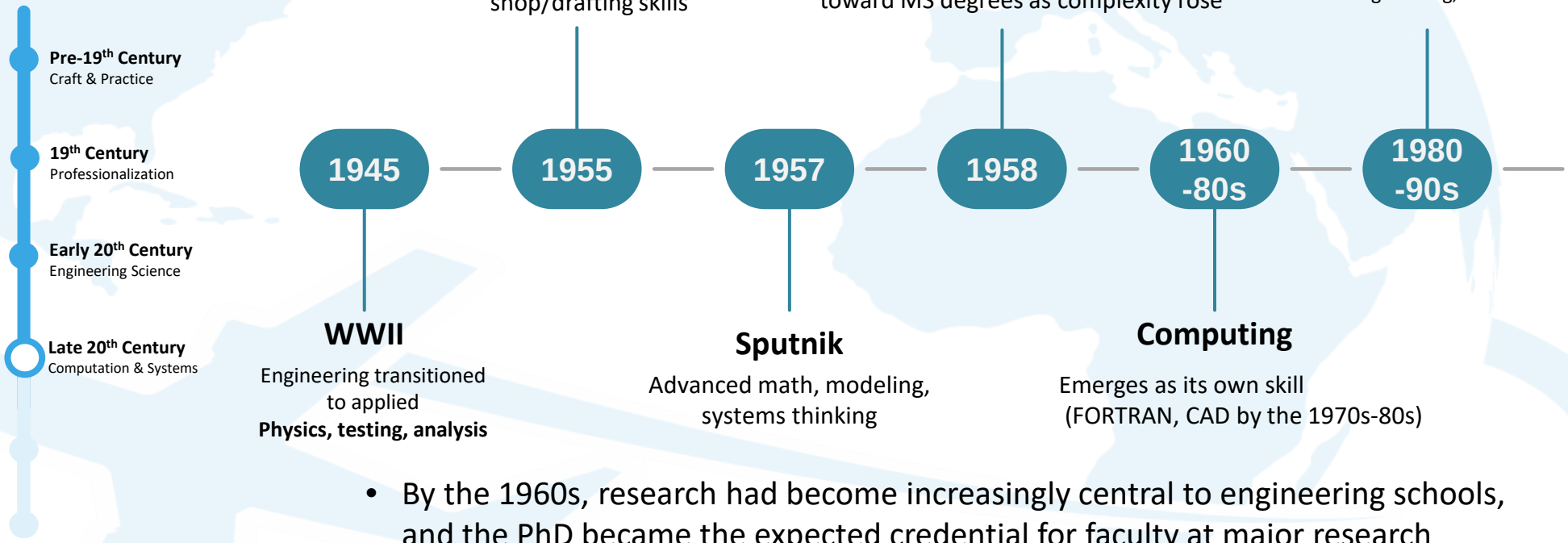
Radar School, MIT [6]



First jet propulsion engine by Frank Whittle, 1938 [7]

War accelerates Technology out of necessity

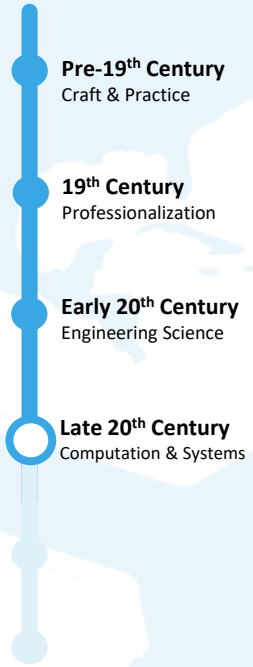
Engineering by Analysis and Computation



- By the 1960s, research had become increasingly central to engineering schools, and the PhD became the expected credential for faculty at major research universities
  - BS: practicing engineer
  - MS: advanced specialization
  - PhD: creation of new engineering knowledge / research
- **This hierarchy largely survives today**

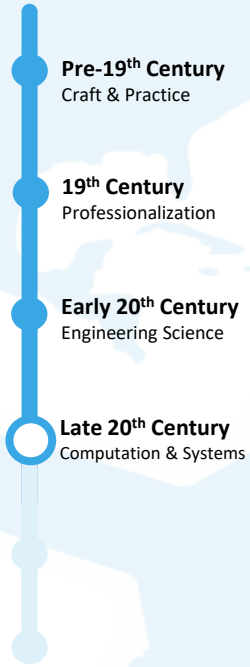
ASEE: American Society for Engineering Education

Engineering by Integration



- Engineering products become dramatically more complex
- No individual can understand every component. Therefore, the engineer's job increasingly shifts from designing components toward **designing and integrating complex systems**
- At the same time, computation transforms engineering
  - The toolkit is now CAD, CAE, CFD, FEA, numerical optimization, and simulation
- By the 1990s, the industry was arguing that technically excellent graduates **were not necessarily fully prepared for modern engineering organizations**
- This contributed to ABET's Engineering Criteria 2000 (EC2000), adopted in 1997
  - ABET shifted accreditation away from simply specifying courses toward evaluating what **graduates could actually do**

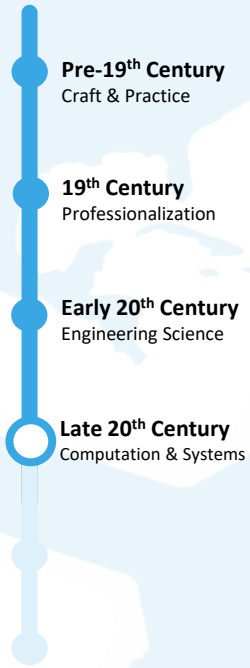
Engineering by Integration



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- At th
  - T
- By th
- **were not necessarily fully prepared for modern engineering organizations**
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  - ABET shifted accreditation away from simply specifying courses toward evaluating what **graduates could actually do**

Engineers must solve complex problems, design under economic/social/environmental constraints, communicate, work in teams, experiment, exercise ethical judgment, and acquire new knowledge as needed

Dr. John MacMasters' - "Desired Attributes of an Engineer" – 1990s



Technical Knowledge & Perspective

- **A good understanding of engineering science fundamentals**
  - Mathematics (including statistics)
  - Physical and life sciences
  - Information technology (far more than computer literacy)
- **A good understanding of design and manufacturing processes**

(i.e., understands engineering)

- **A multi-disciplinary, systems perspective**
- **A basic understanding of the context in which engineering is practiced**
  - Economics (including business practice)
  - History
  - The environment
  - Customer and societal needs

Professional Skills & Personal Attributes

- **Good communication skills**
  - Written
  - Oral
  - Graphic
  - Listening
- **High ethical standards**
- **An ability to think both critically and creatively — independently and cooperatively**
- **Flexibility — the ability and self-confidence to adapt to rapid or major change**
- **Curiosity and a desire to learn for life**
- **A profound understanding of the importance of teamwork**
- **Global awareness (knowledge of at least one language other than English)**

Diversity — wanted and needed

Aviation New Entrants

International Council of the Aeronautical Sciences

- **Pre-19th Century**
  Craft & Practice
- **19th Century**
  Professionalization
- **Early 20th Century**
  Engineering Science
- **Late 20th Century**
  Computation & Systems
- **21st Century**
  Digital Engineering



Hydrogen Propulsion



Hybrid-Electric Propulsion



Supersonic Commercial Aircraft



Blended wing body Aircraft



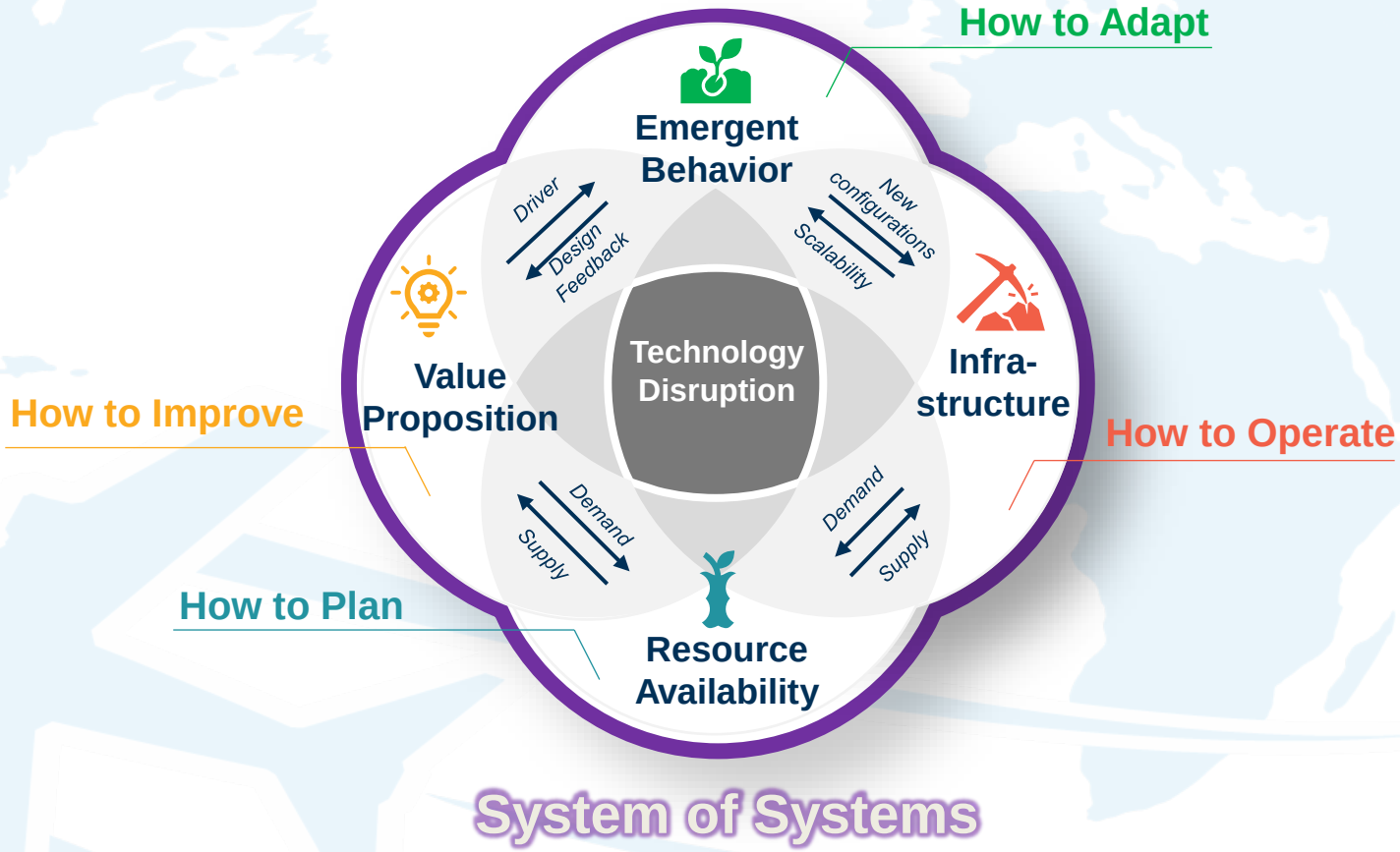
Transonic Truss-Braced wing Aircraft



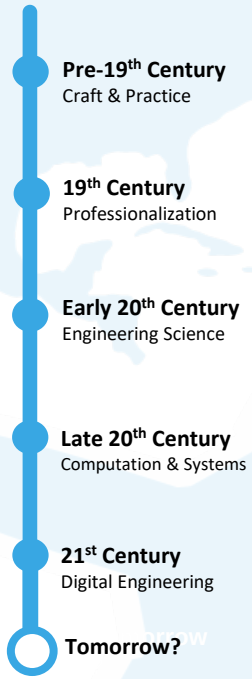
EVTOL

Need for Systems of Systems Thinking

International Council of the Aeronautical Sciences



Engineering by Architecting - “Orchestrating”



- AI, digital threads, autonomy, and increasingly connected engineering tools will potentially shift the engineering value from knowing how to solve to **knowing what problem should be solved**
- As tools become increasingly capable of performing analysis, the differentiating skill of the engineer **moves upward, from execution toward problem formulation, intent, judgment, integration, and decision-making**

Architecting

“the ability to formulate an engineering problem, coordinate the people, models, disciplines, data and AI tools used to solve it, and exercise judgment over the resulting decisions”

- The AI tools may perform pieces of the analysis
- <u>The engineer remains accountable for the coherence of the whole</u>

The Ridiculous, Dangerous, now Self-Evident…

- **Pre-19th Century** Craft & Practice
- **19th Century** Professionalization
- **Early 20th Century** Engineering Science
- **Late 20th Century** Computation & Systems
- **21st Century** Digital Engineering
- **Tomorrow?**



Basement News — Saturday, April 5, 1986

AP photo

Math teachers protest against calculator use

Elementary school math teachers staged a protest yesterday opposing the use of calculators in grade school classrooms. The teachers argue that allowing students to use calculators too early could hinder their understanding of basic math concepts.

Protest at the 1986 National Council of Teachers of Mathematics annual meeting in Washington, D.C

1986: Claims that Calculators will undermine learning

2026: AI will undermine learning

New tools do not necessarily eliminate skills; they change which skills create value

What Skills are Needed in Today's Context?

International Council of the Aeronautical Sciences

Many of the skills discussed are still applicable today and remain true

Law, Philosophy, and Argumentation

- Understanding consequences
- Defending decisions
- Applying the scientific method

Communication and story-telling

Ability to convey a story from beginning to end

Systems thinking and problem formulation

- Asking the right questions
- Building the right approach
- Making abstractions

Digital & AI literacy

Ability to develop, use and connect tools

Human judgement & Leadership

- Collaboration
- Accountability
- Empathy

Safety and regulatory Awareness

- Understanding the industry standards
- Mitigating risks
- Engineering the right product

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3. Grinter, L. E., "Report on Evaluation of Engineering Education," *Journal of Engineering Education*, 1955
4. Ferguson, E. S., *Engineering and the Mind's Eye*, MIT Press, 1992
5. National Academy of Engineering, "*The Engineer of 2020: Visions of Engineering in the New Century*", The National Academies Press, 2004
6. Sheppard, S. D., Macatangay, K., Colby, A., and Sullivan, W. M., "*Educating Engineers: Designing for the Future of the Field*", Jossey-Bass, 2009
7. Trevelyan, J., "*The Making of an Expert Engineer*", CRC Press, 2014

Resilience, risk sharing and capability development in the Swedish Aeronautical industry



The challenges and possibilities for the small but forward leaning nation in military aviation

P-O Marklund

CTO, Saab Aeronautics



Recilience

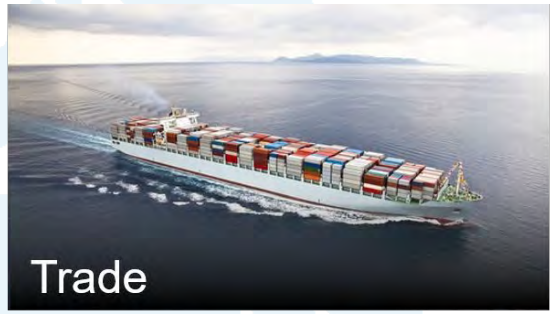

Keeping people and society safe
SAAB


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Sweden

- 10 million people
- Strong engineering heritage
- Industrial companies like
  - Ericsson
  - ABB
  - Scania
  - Volvo
  - Husqvarna
  - Saab
- Less funding compared to other nations
  - Risk sharing
  - Strong collaboration culture















Small Scale – Forward Leaning



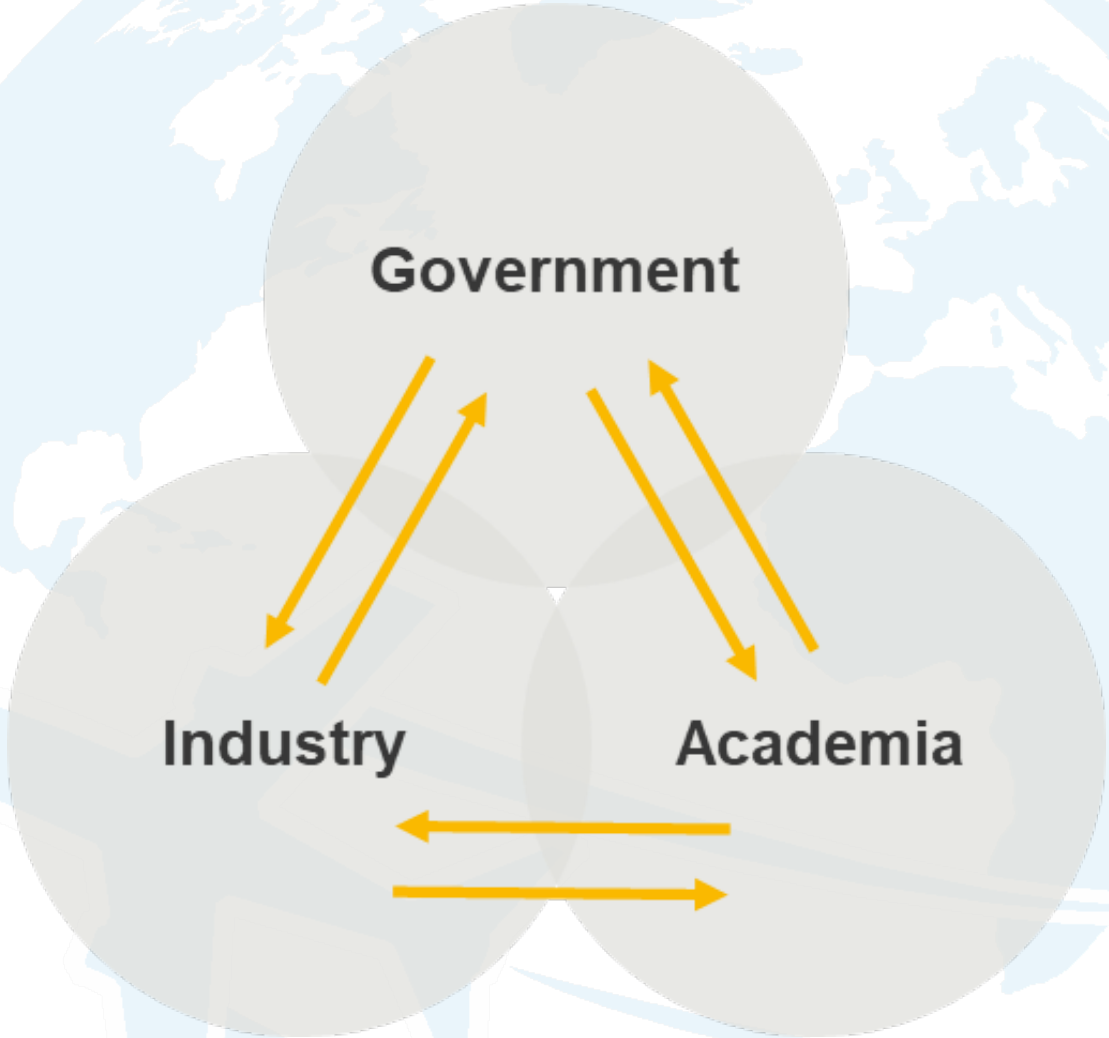

A 400-year legacy of defence and security


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OEM for military aviation systems?

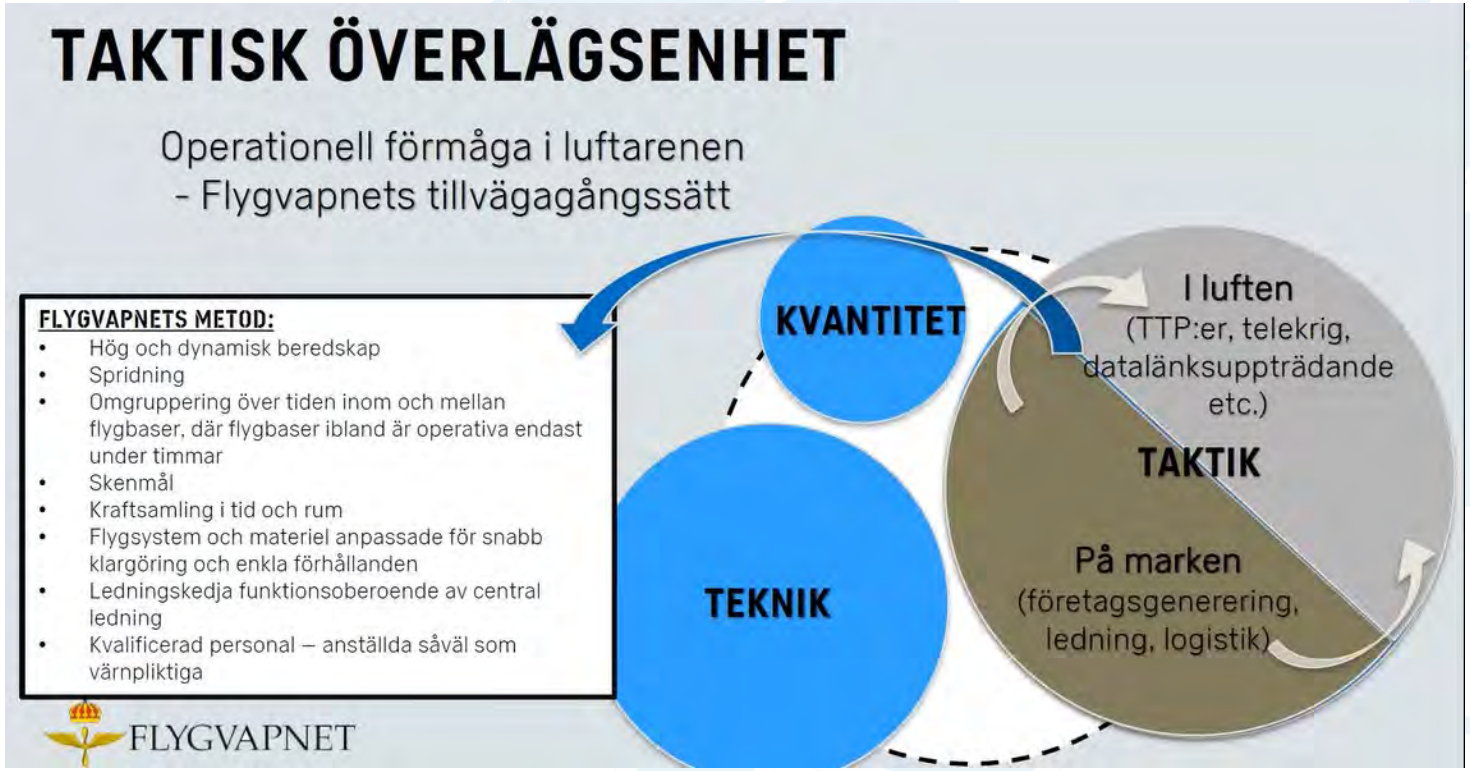
- **The ability to take decisions that affects the overall capability and operational relevance of the system**

- **The capability to hold permits such as:**
  - *Design Organisation Approval Certificate*
  - *Production Organisation Approval Certificate*
  - *etc*

- **The capability to “*buy from*” and/or “*develop with*” partners**
  - *To have the capability to lead a partner or subcontractor, integrate the result and remain responsible towards the authorities*



Keeping the tactical superiority



- Design for tactics
- More development takes place closer to the customers or by the customers



Original Equipment Manufacturer relevancy

- In an era of rapid technological change—where aspects like new propulsion systems, autonomy, new materials, quantum and digital twins redefine the aeronautical landscape—the OEM must not only absorb innovations, but *shape them into integrated, certifiable, and market-relevant products*.
- This demands continuous *investment in education, research, and industrial capabilities focused on product realization*.

Sweden's ability to act as an OEM for advanced systems such as fighter aircraft has historically created high industrial value and strategic autonomy. This capability is rare, even among developed nations, and should be considered a national asset.





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ROADMAP

SAAB

Swedish Air Force
Concept Programme

2026 - 2030 | **2031 - 2035** | **2036 - 2050**

- 1st Flight Demo A1
- 1st Flight Demo A2
- 1st Flight Prototype A3
- In Service (IOC)
- Core Fighter Development



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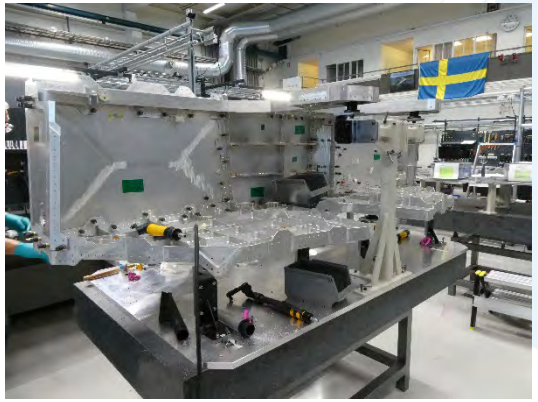
Demo A1

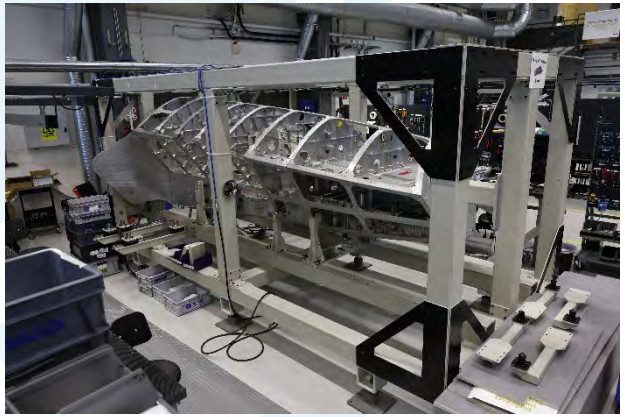


SUPERSONIC DEMONSTRATOR

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ON TRACK













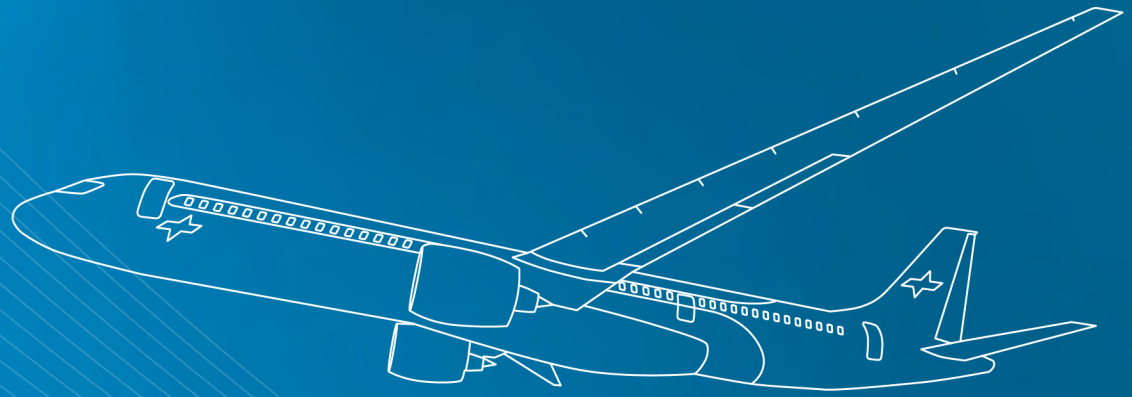


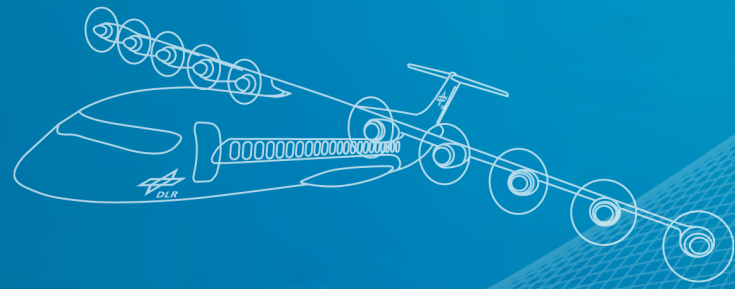

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Conclusions

- With the ongoing programs in Sweden at the moment, e.g. Gripen E/F, Global Eye and T-7, we at the moment have a unique position to develop and build capability from.
- The Swedish concept program will evolve our sovereign capabilities
- We have a well-functioning collaboration between industry, government and academia with several joint projects and boundary-spanners with key universities that assures both academic as well as industrial relevance in the research.
- Hurdles will exist, but we will continue to fight for our OEM capability, from 1937 and forward







DLR CONTRIBUTION AND STRATEGY FOR CLIMATE-COMPATIBLE & COMPETITIVE AIRLINERS OF THE FUTURE

GENERAL LECTURE 4 Aeronautics Outlook - Directors Cut



16th September 2026, ICAS 2026 Congress Sydney

Dr. Markus Fischer, Divisional Board Member Aeronautics

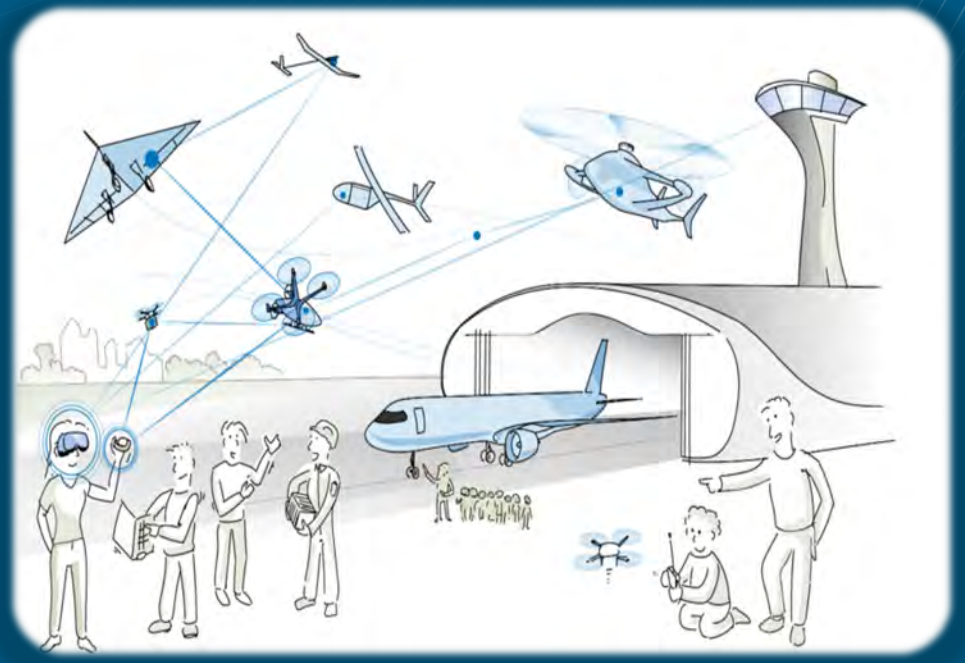
DLR

Shaping the Air Transport System of Tomorrow
Contributions of DLR‘s Aeronautics Research

Aeronautics Research

Industry, Economy and Public Stakeholders

- **Architect, Networker, Incubator**
(e.g. LuFo, Clean Aviation, SESAR, …)
- **Continuous exchange of research results with partners**
(e.g. OEMs, SMEs, Airlines, ANSPs, Police, Armed forces …)
- **Knowledge Exchange Platforms to public stakeholders**
- **Innovation and Transfer to Economy**
- **Training of highly qualified staff in/ and for aviation**



DLR‘s Aeronautics Strategy

Vision

DLR is shaping the future of strong, economical, secure and climate-compatible aviation for civil and defense purposes

Mission

DLR is developing world-class technologies, methods and processes in a multi-domain and multi-fidelity approach

Approach

Economic and ecological overall assessment of each technology at air transportation level as a pre-requisite

Continuous exchange & provision of research results with industry, economy, public stakeholders, academia and associations

DLR‘s Aeronautics Strategy



Program Topics

Airframe and Systems

Flight Physics and Aircraft Performance

Propulsion and Power Systems

Air Transport System

Overall assessment of the air transportation system

Climate compatible aviation technologies

Innovative design principles & architectures

Program Topics

Flight Physics and Aircraft Performance

- Efficient technologies
- Intelligent aircraft

Propulsion and Power Systems

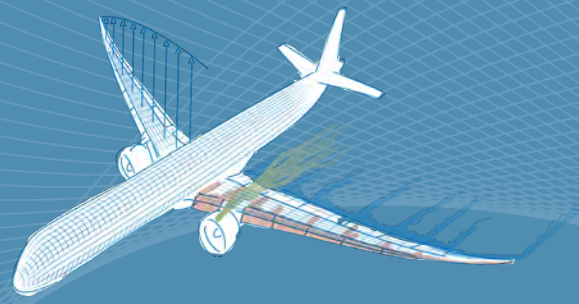
- Propulsion efficiency
- New Energy Carrier

Airframe and Systems

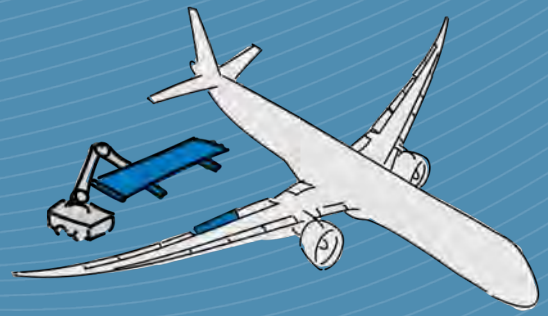
- High rate production
- Intelligent Systems

Air Transport System

- Automation
- Sustainable operations









- **Cutting-edge technologies for efficiency, competitiveness and safety**
- **Digital, AI-enabled design methods and virtual certification**
- **Decrease Time-to-market**

Program Topics

Flight Physics and Aircraft Performance

- Efficient technologies
- Intelligent aircraft

Propulsion and Power Systems

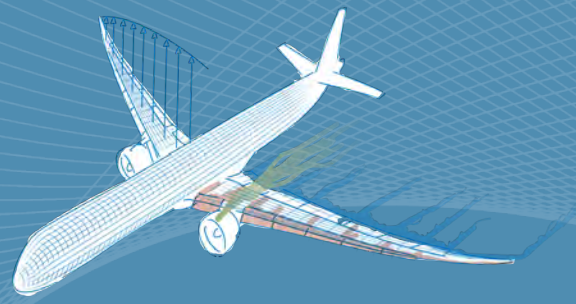
- Propulsion efficiency
- New Energy Carrier

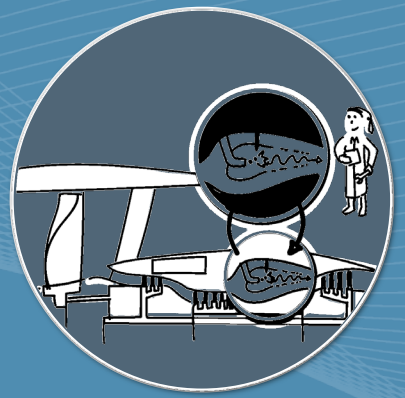
Airframe and Systems

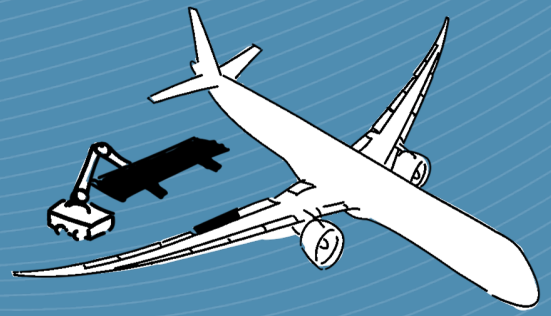
- High rate production
- Intelligent Systems

Air Transport System

- Automation
- Sustainable operations









Program Topics

Flight Physics and Aircraft Performance

- Efficient technologies
- Intelligent aircraft

Propulsion and Power Systems

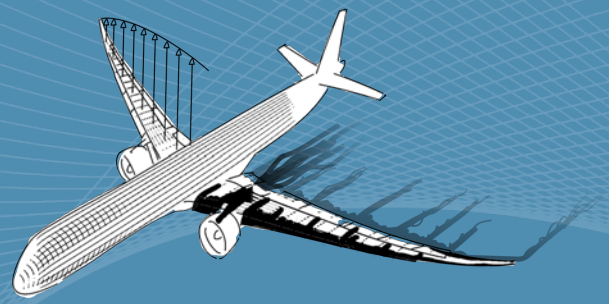
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Airframe and Systems

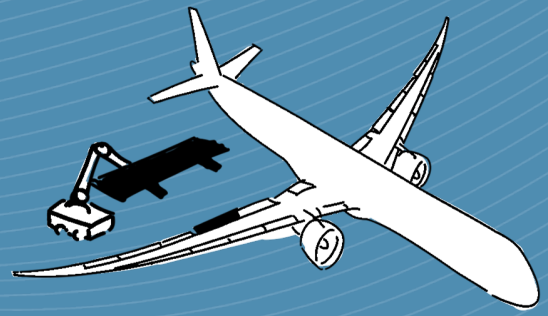
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Air Transport System

- Automation
- Sustainable operations





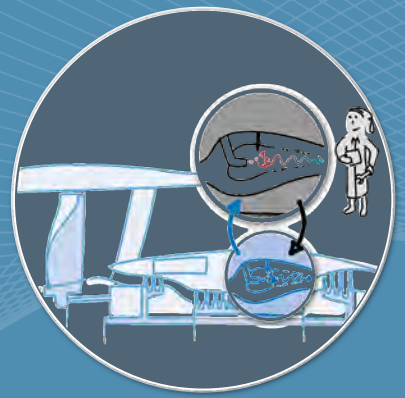


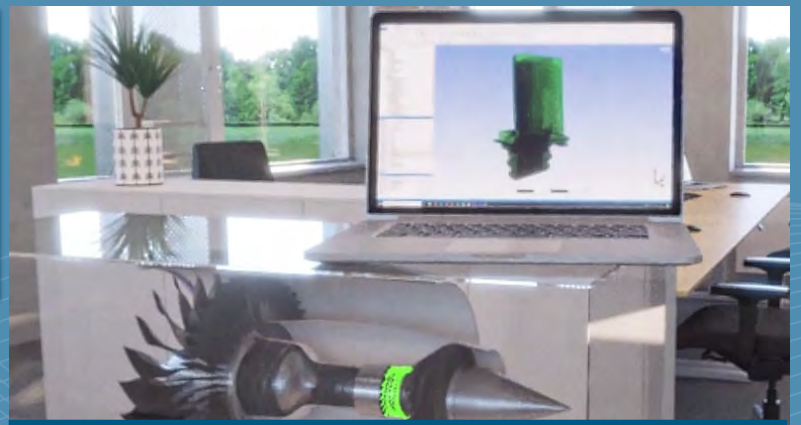


Program Topics

Propulsion and Power Systems

- Propulsion efficiency
- New Energy Carrier

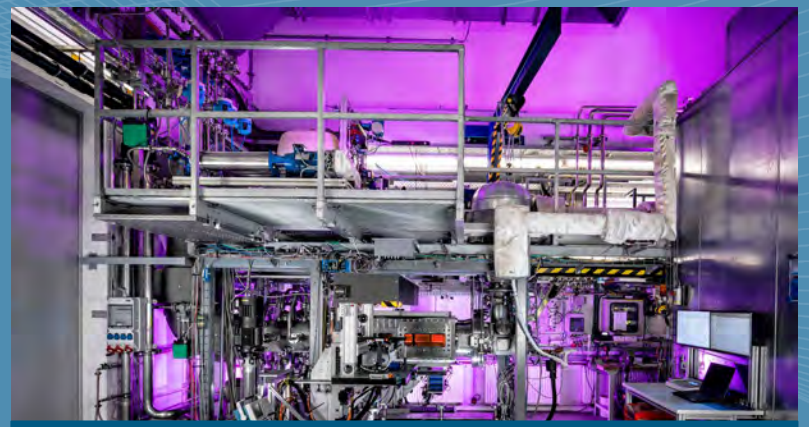




Test & Simulation for Gas Turbines



Propulsion Technology



Combustion Technology



Electrified Aero Engines

Program Topics

Flight Physics and Aircraft Performance

- Efficient technologies
- Intelligent aircraft

Propulsion and Power Systems

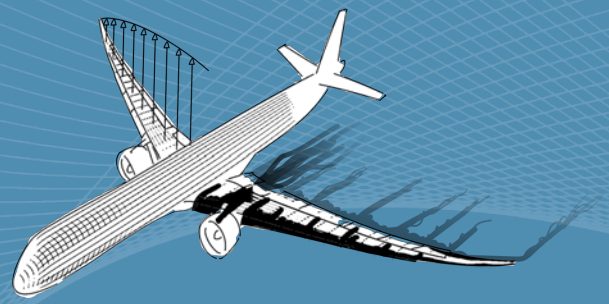
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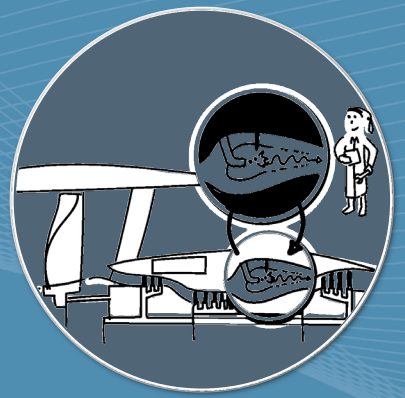
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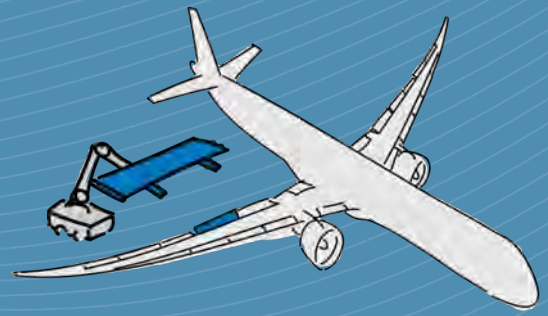
- High rate production
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Air Transport System

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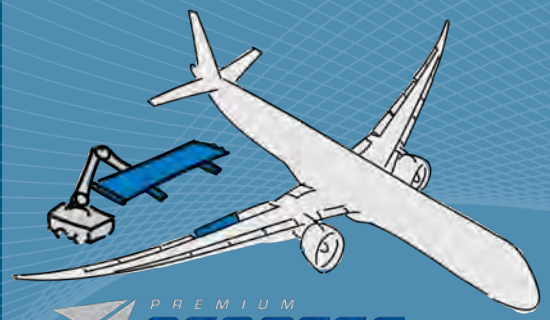


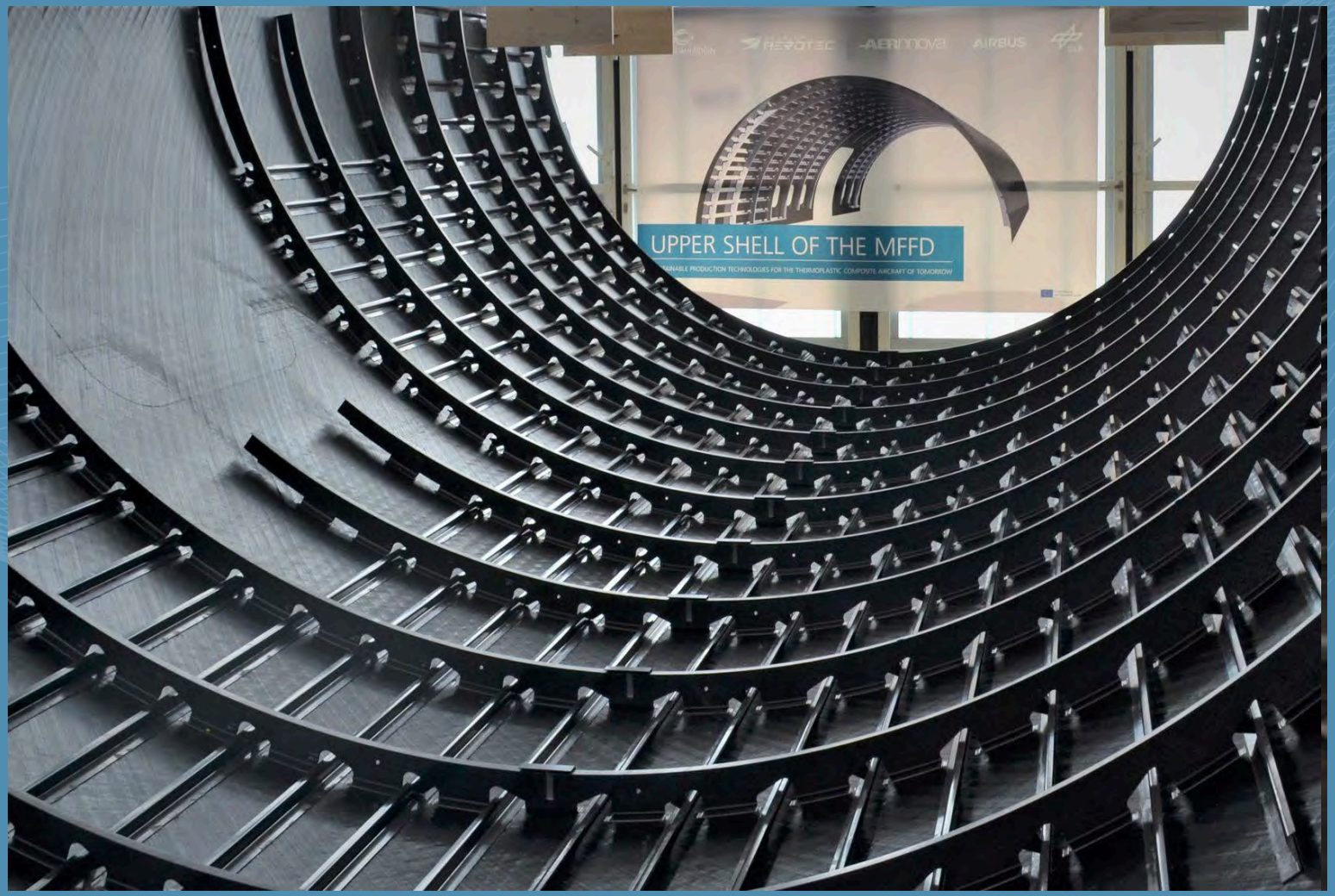
- **Cutting-edge technologies for efficiency, competitiveness and safety**
- **Digital, AI-enabled design methods and virtual certification**
- **Decrease Time-to-market**

Program Topics

Airframe and Systems

- High rate production
- Intelligent Systems





Program Topics

Flight Physics and Aircraft Performance

- Efficient technologies
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Propulsion and Power Systems

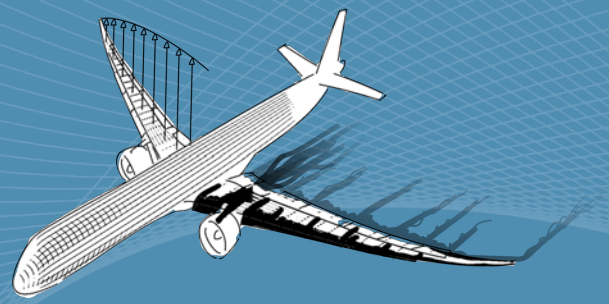
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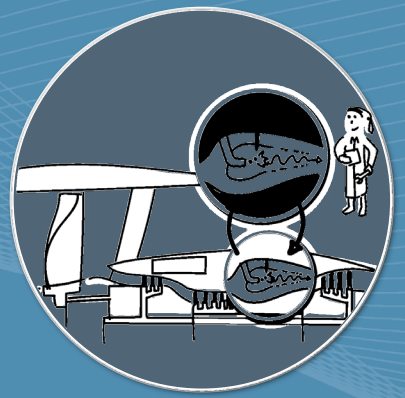
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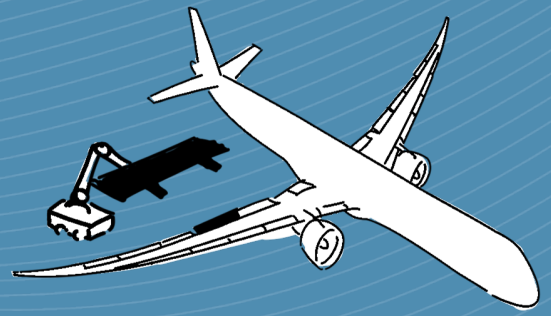
- High rate production
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Cross-Topics Activities

Integrated Design Principles and Architectures

- New product architectures
- Virtual certification

Overall Assessment on Air Transport System Level

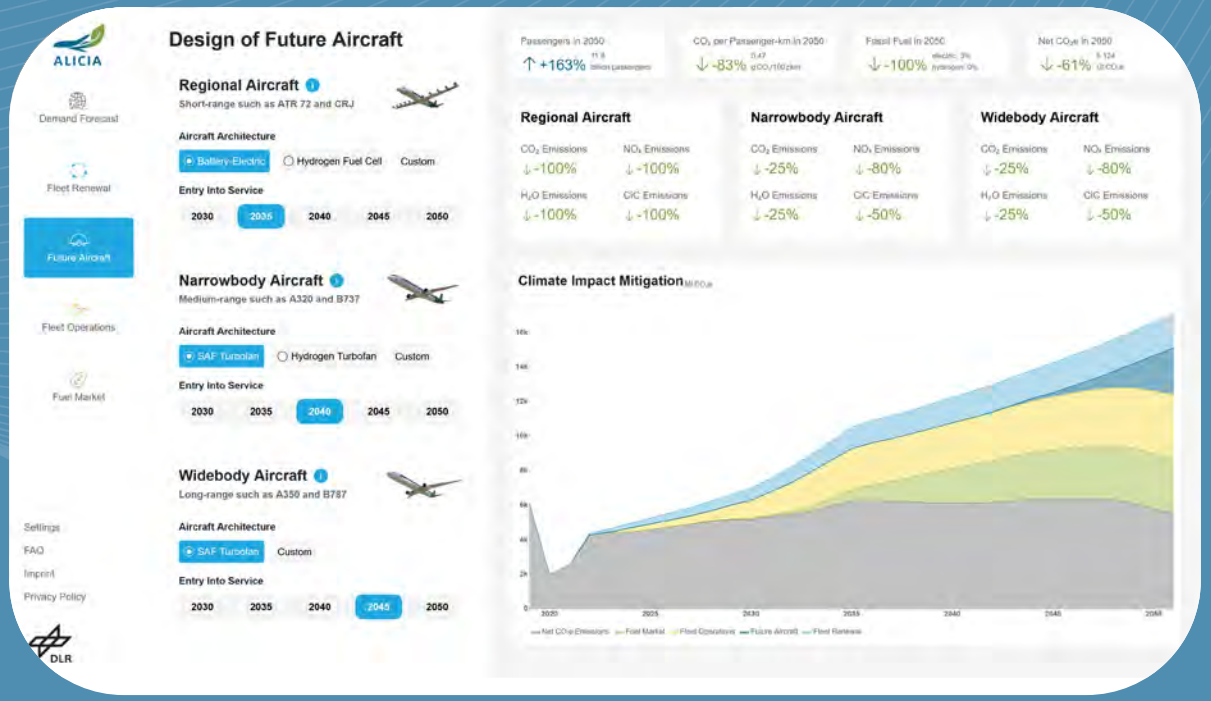
- Economic assessment
- Supply chains & regulations











Conclusion

- Meet future mobility demands and social acceptance
- Aviation as part of a resilient, competitive and an autonomous economy
- Assure the key role of aviation as fastest, most reliable and indispensable means for the whole economy
- Maintain safety and security at highest level
- Achieve climate compatibility including noise reduction

